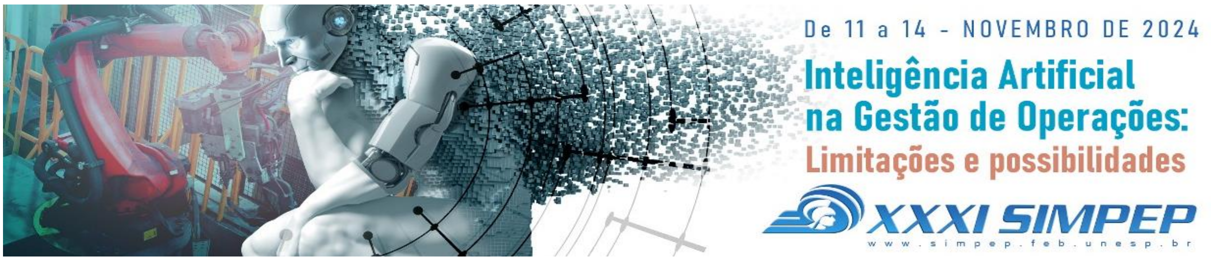

The socioeconomic effects of gold mining in the Jacobina region, Brazil: A quantitative assessment

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ÁREA: *3. PESQUISA OPERACIONAL*
SUBÁREA: *3.3 - PROCESSOS DECISÓRIOS*

ABSTRACT: *THE INDUSTRIAL ACTIVITY OF GOLD PRODUCTION HAS A POSITIVE SOCIAL IMPACT ON THE REGIONS WHERE IT IS LOCATED. THE PRESENT STUDY OBJECTIVE WAS TO ASSESS THE RELATIONSHIPS BETWEEN SOCIAL ASPECTS AND REGIONAL DEVELOPMENT OF THE MUNICIPALITY OF JACOBINA, BAHIA, BRAZIL. EVALUATING THE POSSIBILITY OF A RELATIONSHIP BETWEEN GOLD PRODUCTION LEVELS AND THE SOCIAL FACTORS OF A REGION (SUCH AS HOSPITALIZATION LEVELS, SCHOOL ENROLLMENT, EMPLOYABILITY, AND VEHICLE FLEET) CAN BE HELPFUL IN THE DECISION-MAKING PROCESS OF PUBLIC AUTHORITIES. THEREFORE, IT HELPS CREATE PUBLIC POLICIES THAT PROMOTE SPECIFIC REGIONS, ECONOMIC AND SOCIAL DEVELOPMENT. THE SPEARMAN CORRELATION (R) METHOD WAS APPLIED USING 95% SIGNIFICANCE ($P \leq 0.05$). THE RESULTS SUGGESTED A DIRECT AND SIGNIFICANT RELATIONSHIP BETWEEN GOLD PRODUCTION, THE NUMBER OF EXISTING BUSINESSES, AND OTHER INDIRECT RELATIONSHIPS. WE CONCLUDED THAT THE INDUSTRIAL GOLD MINING ACTIVITY POSITIVELY INFLUENCED SOCIAL FACTORS IN THE STUDIED REGION. FOCUSING ON JACOBINA, THIS RESEARCH EXAMINED THE SOCIAL AND ECONOMIC CONSEQUENCES OF GOLD MINING. HOWEVER, DUE TO LIMITED DATA AVAILABILITY, THE ENVIRONMENTAL IMPACTS OF GOLD MINING COULDN'T BE INCLUDED IN THE ANALYSIS.*

KEYWORDS: *GOLD MINING INDUSTRY; STATISTICS; SPEARMAN CORRELATION; ECONOMIC IMPACT; SOCIAL IMPACT.*

1. INTRODUCTION

With the predominance of gold production in the world, Brazil has stood out with large extraction volumes, with 1200 tons produced in the 18th century. Due to the promising sources of this mining activity in Minas Gerais, Goiás, Mato Grosso, and Bahia, in the last 120 years, several mining industrial projects have appeared, predominately of English companies. For approximately 20 years, the Jacobina region in Bahia, Brazil, has received investments to reactivate and increase gold production through large foreign companies. This research aims to analyze the relationship between gold production in the Jacobina region and the social factors that reflect on the population's quality of life. Quantitative methods such as correlation and regression analyses were used to measure the degrees of relationship between the variables studied.

The industrial mining sector, relative to other industries, is often regarded as "resistant" to technological integration. This characterization stems from the substantial investments in technology associated with mining projects and deposit exploration. As in gold mining, the stimulus for integrating new technologies (or old technologies with incremental renewals) has two factors. The first is that gold is one of the minerals for which demand has driven great economic development in the last two decades. The second factor is associated with the aspects of gold. As it comprises tiny mineral components, extracting large amounts of material is essential to obtain minimal metal (Hanai, 1998).

Mining significantly influences territories due to its economic focus on expanding and developing deposits. The sector is driven by competition for land use and the resulting adverse environmental impacts. Like other extractive industries, mining practices yield considerable social and environmental consequences. However, its effects can be uniquely detrimental, often leaving irreversible environmental damage. Various impacts adversely affect all living beings, including groundwater pollution, deforestation, air contamination, spring depletion, soil contamination, noise pollution, and respiratory diseases. Social impacts are also significant, as mining companies disrupt local communities' way of life and social structure, often employing tactics like land purchases, job offers, and intimidation to displace populations. Consequently, territorial loss often becomes inevitable (Reis, 2017).

The mining sector generally encompasses areas designated for mineral extraction, equipment installation, and operational organization. Evaluating mineral deposits often necessitates surface disruption, which can undermine the balance of biomes and ecosystems, thereby altering the socio-spatial dynamics of local or even regional areas. Consequently, the outcomes of mining activities can have significant and far-reaching effects (Vieira, 2011).

Jacobina, a municipality in the interior of Bahia state, Brazil, is characterized by a gold mining-based economy. Multiple mining companies operate within the region, actively extracting mineral resources, forming the city's economic bedrock. The introduction of mining companies in the region catalyzed an economic boom, significantly influencing commercial activity. Critical indicators of local development encompass environmental, social, cultural, and economic dimensions. Consequently, this development trajectory necessitates evaluating local progress through a multifaceted framework rather than a narrow political and economic lens. This approach aims to ensure equitable quality of life and economic growth while fostering broader social collaboration (Carvalho and Angelo, 2016).

Worldwide, the increase in searches for raw materials is becoming quite common, enabling opportunities for the mining market. Companies must take measures to generate less impact on the environment. Although the gold extractive activity in Jacobina is economically profitable, it positively impacts the region's economy and socio-environmental spending to the same extent. The waste dam constructed by “Jacobina Mineração e Comércio (JMC)” has resulted in significant environmental degradation, notably the destruction of native forests, as it has directly affected the livelihood of the neighboring community, particularly region of “Canavieiras”. Previously, arable land has been transformed into a waste repository, accumulating substantial tailings. This land-use conversion has had deleterious effects on the local ecosystem and community (Souza, 2013).

Mineral manufacturing is an operation of significant prominence, whether providing raw materials or promoting local, national, or even global economic growth. Starting in the 17th century, when gold was discovered in the Jacobina mountain range, stimulating mining labor to the urban center, it initiated a process of growth and progression of cities through change and the establishment of the city population. It is known today as the "City of Gold" (Farias, 2008).

The strategic and tactical project of the mineral sector requires environmental analyses, health projects, and others. There must be a radical change in the Mining Code and the understanding of the domain, the data, and the samples carried out by government agencies and private companies. New legal conduct in other countries favors the system, corporations, and the use of data from geochemical surveys in Brazil (Melfi et al., 2016).

This study proposes to answer the research question: Did gold production in Jacobina improve the population's quality of life?

2. BACKGROUND

This section presents and details some concepts and research carried out on gold mining and its impacts.

2.1 Gold Production

The global production of gold in the 19th century was defined by the gold rush, which began in 1848, with the United States Gold Rush, when the discovery of mining deposits occurred, stimulating European society to explore controlled lands by the Indians. Later, the United States had two gold rushes in Alaska after the Civil War in Colorado and the other at the end of the 19th century (Neto, 1998). In recent years, gold has seen a gradual demand, showing a considerable increase in gold production worldwide. It highlights the existence of sublime gold reserves held by the central banks of the United States and Europe, estimated at 35 thousand tons, which, through planned disinvestment, constitute a representative portion of the annual supply on the international market (Andrade et al., 2000). On the other hand, the methods used by corporations of large multinational teams result, in global proportions, through the accumulation of extractive projects - mainly polluting activities that cause irregularities in health and the environment - in the global South and the periphery in general (Fernandes and Araujo, 2016).

Relating the averages of the numerous hypotheses provided for the national manufacture of gold agglomerates in past periods, a total union of 2,952 tons has been estimated since 2000. It is worth noting that around 63% of the total would be manufactured during the 20th century since, at that time, the majority (78%) would be concentrated between 1980 and 2000 (Vale and Hermann, 2002).

Brazil is a prominent country in world gold production, showing its economic influence. However, this development is practically attributed to the exclusive growth of mining production in the Amazon region. At the end of the 1980s, official manufacturing by miners reached approximately 90% of total manufacturing. At the beginning of 1988, this production began to decline as a result of the reduction in the gold price, which ended up costing an average of approximately US$ 30.00/g, and the depletion of the surface stock in which the gold usually appears enriched and with indelicate granulations enabling the extraction through rudimentary techniques (Porto et al., 2002).

Industrially, the substance of gold is diverse and widely used in various industries.

Gold is also used in jewelry, medical and dental parts, and electronics. As it is a very malleable metallic mineral element, it is sold industrially as ingots, wires, bars, sheets, and alloys (Neto, 1998). Jacobina Mineração e Comércio (JMC) - Yamana Gold Inc. - is an institution that operates in the mining and exploiting gold and is located in the city of Jacobina, Bahia. The gold mines marked by JMC are located in the Jacobina Mountains (João Belo, Morro do Vento, Canavieiras, and Basal mines) (de Jesus et al., 2011). In this context, it is appropriate to consider the division between process and product technology. It primarily talks about the way of manufacturing, which can be rustic (for example, a gold mine) or make use of more developed technologies available for gold extraction, with mining companies working with information and communication technology (ICTs), inserted into devices and operating system controls, possibly remote control operation (Melfi et al., 2016).

2.2 Environmental impact and assessment

Industrial gold mining has significant environmental impacts, involving extensive use of hazardous chemicals, water pollution, air pollution, and land degradation. The adverse effects extend to ecosystems, human health, and local communities.

Industrial gold mining often involves the use of hazardous chemicals such as mercury and sodium cyanide, leading to severe environmental contamination. These chemicals are persistent pollutants that can bioaccumulate aquatic life and pose serious health risks to humans and wildlife (Tarras-Wahlberg et al., 2001). Acid Mine Drainage (AMD) results from the oxidation of sulfide minerals, creating sulfuric acid, which leaches heavy metals from surrounding rocks, contaminating water bodies and soils. This process can persist long after mining activities have ceased, making remediation challenging and expensive (Laker, 2023). Industrial gold mining often results in elevated levels of metals like arsenic, lead, and cadmium in water sources, posing severe risks to aquatic life and human health (Chen et al., 2018).

Mining activities generate substantial dust and emissions, including particulate matter that can cause respiratory issues in humans and animals. These emissions also contribute to greenhouse gas concentrations, exacerbating climate change (Farjana et al., 2018). Gold mining leads to extensive deforestation and habitat destruction, which disrupts local biodiversity and ecosystems. This is especially pronounced in tropical rainforest regions, where large areas are cleared for mining operations (Porgo and Gokyay, 2017). Removing vegetation and topsoil leads to increased soil erosion, further degrading the land and reducing its agricultural potential (Mudd, 2007).

Communities near industrial gold mining operations often suffer from exposure to toxic substances like mercury and cyanide, leading to serious health issues, including neurological and developmental problems (Hilson, 2002). Contaminated water sources due to mining activities result in increased waterborne diseases and other health problems among local populations (Kumah, 2006). Industrial gold mining has severe environmental impacts, including chemical pollution, water and air pollution, land degradation, and significant health risks to local communities. Addressing these impacts requires stringent regulations, sustainable mining practices, and effective monitoring.

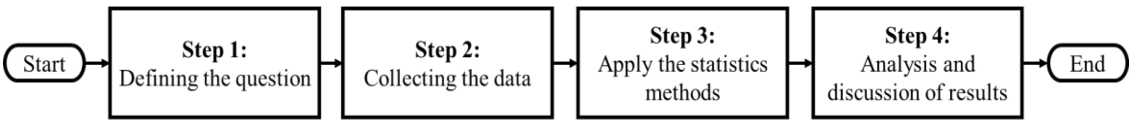
Assessing the environmental impact of gold mining activities involves a systematic approach to identify, evaluate, and manage the potential adverse environmental effects. Here are the critical steps involved in conducting an environmental impact assessment (EIA) for gold mining activities.

3. METHODS

The approach of this research is quantitative correlational design, in which statistical methods were used to evaluate the relation between data on gold production and economic and social factors of the municipality of Jacobina in Brazil.

Data regarding gold production and social factors of the municipality of Jacobina, Brazil, were retrieved from IBGE (Brazilian Institute of Geography and Statistics - https://www.ibge.gov.br/). The research steps can be described in a flowchart representing the research algorithm. It is possible to replicate all study steps and obtain the same results using the algorithm. Figure 1 presents the flowchart of research.

Figure 1 – Flowchart of research



The following subtopics present the explanations of the research steps.

Step 1 – Defining the question: The research question is "Did gold production in Jacobina improve the population's quality of life?"

Step 2 – Collecting the data: Data collection was related to the factors that might correlate with gold production, which were the economic (quantity of companies, vehicle fleet) and social (school enrollment, employed people, hospital admissions) factors. Data were retrieved from IBGE (Brazilian Institute of Geography and Statistics - https://www.ibge.gov.br/).

Step 3 – Statistical analysis: The Spearman Correlation was applied to create a correlation matrix between studied factors. After that, the significance of each correlation was calculated.

Step 4 – Analysis and Discussion of Results: The analysis of results started by determining the significance of the correlation. Only correlation values > 0.7 were considered significant for this research.

For the present study, 11 factors (independent variables) were considered, as listed in Table 1. The first factor, Gold Production (A), is the independent factor, and the remaining ten factors are dependent and were analyzed separately from factor A. According to the aim of this research, statistical methods were used to find some relation between gold production and the ten other factors selected.

Table 1 – Legends of factors

Index	Description
A	Gold Production / t
B	Hospitalizations for diarrhea by SUS / 100 thousand inhabitants.
C	Daycare enrollment
D	Fundamental School Enrollment
E	Number of companies
F	Salaried employed staff
G	Average monthly minimum wage
H	Salaries and other remuneration / $
I	Car Fleet
J	Motorcycle Fleet
K	Bus fleet

Because of the small quantity of elements in the variables, it was not necessary to verify the data's behavior. Therefore, we calculated the correlation analysis. Since the behavior of variables was not Gaussian, the recommended correlation method of Spearman was used, equation 1.

$$r = 1 - \frac{6\sum d_i^2}{n(n^2-1)},\ \ -1 < r < 1 \qquad \text{Eq. 1}$$

Where r = Spearman's rank correlation coefficient; d_i = difference between two ranks of each observation; and n = number of observations.

4. RESULTS AND DISCUSSION

The correlation values (r) results were calculated and shown in Table 2. For this research, the p-value considered significant is p≤0.014.

Table 2 – Matrix of correlation (r) of the variables (A to K) with the respective p-value. The highlighted values are those considered significant.

	A	B	C	D	E	F	G	H	I	J	K	Correlation
A	**1**	-0.11	0.11	0.29	0.86	0.11	0.07	0.21	0.25	0.25	0.25	r
		0.819	0.819	0.535	0.014	0.819	0.879	0.645	0.589	0.589	0.589	p-value
B		**1**	-0.64	0.54	-0.29	-0.89	-0.70	-0.93	-0.86	-0.86	-0.86	r
			0.119	0.215	0.535	0.007	0.082	0.003	0.014	0.014	0.014	p-value
C			**1**	0.00	0.54	0.50	0.64	0.75	0.86	0.86	0.86	r
				1.000	0.215	0.253	0.119	0.052	0.014	0.014	0.014	p-value
D				**1**	0.36	-0.50	-0.48	-0.36	-0.21	-0.21	-0.21	r
					0.432	0.253	0.273	0.432	0.645	0.645	0.645	p-value
E					**1**	0.32	0.29	0.50	0.61	0.61	0.61	r
						0.482	0.535	0.253	0.148	0.148	0.148	p-value
F						**1**	0.88	0.93	0.86	0.86	0.86	r
							0.010	0.003	0.014	0.014	0.014	p-value
G							**1**	0.91	0.82	0.82	0.82	r
								0.004	0.023	0.023	0.023	p-value
H								**1**	0.96	0.96	0.96	r
									0.000	0.000	0.000	p-value
I									**1**	1.00	1.00	r
										0.000	0.000	p-value
J										**1**	1.00	r
											0.000	p-value
K											**1**	

Table 2 shows the results of the correlation coefficient calculus. In color gray are highlighted the best results. After analyzing the data in Table 2, some considerations can be related, as follows:

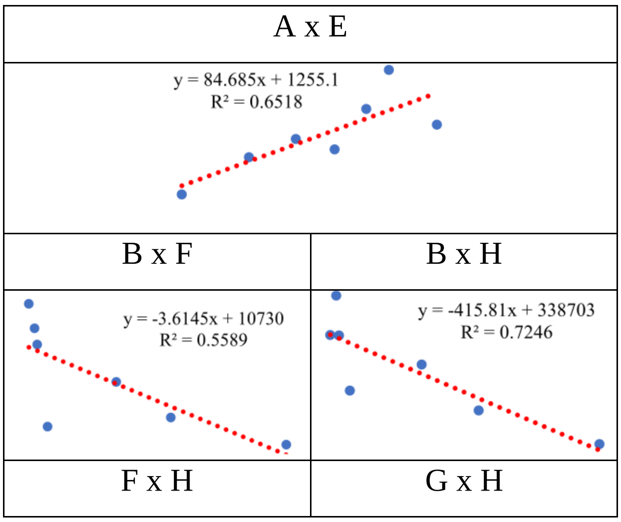
a. The correlation coefficients calculated between Gold Production and each other are ten dependent factors, only with the "Number of Companies" (E) factor. The correlation coefficient is significant, with p-value= 0.014. This suggests that gold production can only directly influence the number of companies registered in the municipality of Jacobina.

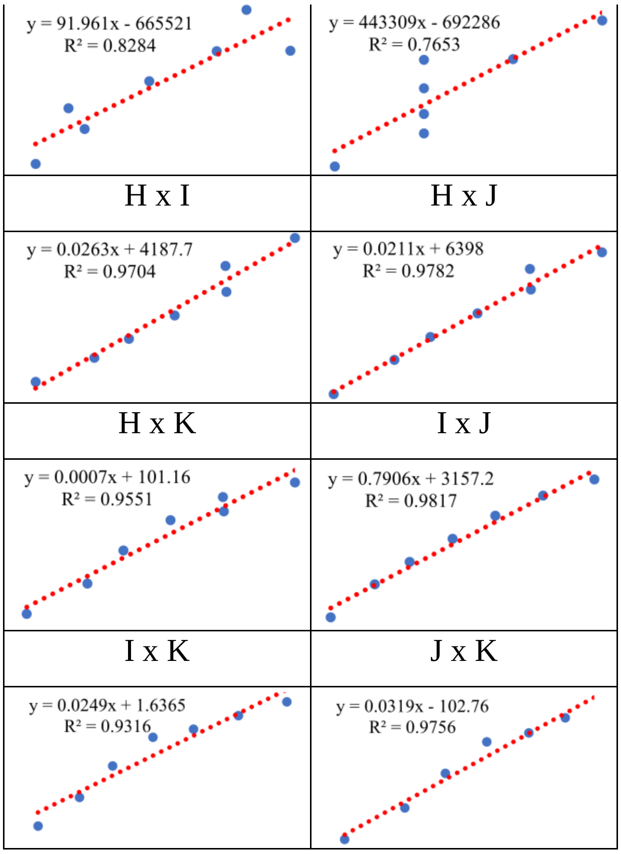
b. Regarding the other 45 correlation coefficients calculated, only ten are significant. Their linear regressions are plotted in Figure 2;
c. The correlation coefficients between Hospitalizations (B) and Salaried employed staff (F) and Hospitalizations (B) and Salaries and other remuneration (H) are inversely significant. It suggests that the level of hospitalizations decreases as the number of salaried employees and salaries increase;
d. The correlations (F x H, G x H, H x I, H x J, and H x K) are significant and have a coefficient above 0.90 (very strong). In this case, there is a suggestion that if salaries and other remuneration (H) increase, the average monthly minimum wage (G) and the fleet of vehicles (I, J, and K) increase, as well.

Finally, it is possible to suppose that Number of Companies (E) is directly responsible for Salaried employed staff (F), Average monthly minimum wage (G), and Salaries and other remuneration (H). It could indirectly influence the vehicle fleet (I, J, and K). Furthermore, it could also be concluded that increasing the population's income through companies creating jobs can improve the level of social factors in a generalized way.

When using the Correlation Coefficient (r), the degree of relationship between two variables is measured. The Correlation Coefficient (r) is the ratio between covariation and the square root of the product of variations between two variables (Fonseca et al., 1938). Table 3 shows the best relation between Gold Production and the other ten social factors. Factor "Number of companies" (E) has the best relation with "Gold Production" (A) with a Determination coefficient equal to 65.18% and correlation coefficient equal to 0.86.

Figure 2 – Positive linear relation between Gold Production and Number of Companies





In Figure 2, we present the linear regression of best results of correlation coefficients. These graphs show that the analyzed variables have a linear relation. In the case of Hospitalizations (B) versus Salaried employed staff (F) and Hospitalizations (B) versus Salaries and other remuneration / $ (H), the relations are negative, that is, when the level of Salaried employed staff or Salaries and other remuneration / $, increase, the level of Hospitalizations decrease.

The studies mentioned in this paper entirely overlook the environmental impacts of gold mining (Hanai, 1998; Reis, 2017; Vieira, 2011; Carvalho and Angelo, 2016; Melfi et al., 2016). This study focused on the social and economic factors impacted by the gold mining industry in Jacobina. The results suggest that activity of gold mining in the region may brings social and economic development.

5. CONCLUSION

The present study used statistical methods to evaluate the possibility of a relationship between the industrial activity of gold production and the economic and social factors of the region where the municipality of Jacobina is located.

Regarding the objectives, it can be concluded that they were achieved, and the results presented some significant data, such as some following correlations:

1. Gold Production and Number of Companies ($r = 0.86$, p-value = 0.014);

2. Hospitalizations and Salaried employed staff (r = -0.89, p-value = 0.007);

3. Hospitalizations and Salaries and other remuneration / $ (r = -0.93, p-value = 0.003);

4. Salaried employed staff and Salaries and other remuneration / $ (r = 0.93, p-value = 0.003);

Other significant results are presented in Table 2, which shows that some correlations are significant. They suggest that gold production can influence a region's economic and social factors, and public measures can be grounded on this information.

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